Final Technical Report
NASA GRANT NO. NGR01-001-013

SHUTTLE, STATION, AND SATELLITE COMMUNICATIONS PROGRAM

(NASA-CR-146860) SHUTTLE STATION, AND SATELLITE COMMUNICATIONS PROGRAM Final Technical Report (Alabama A & M Univ., Normal.) 10 p HC $3.50 CSCL 17B

N76-21257

Unclas
G3/17 26266

Submitted to

MARSHALL SPACE FLIGHT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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March 1974

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ACKNOWLEDGEMENTS

Dr. Glen Weathers is largely responsible for several analyses and computer simulations in the report dealing with the theory and application of spread spectrum systems; Dr. Hrish Saha also assisted in this effort. Mr. Lloyd Ellerbeck and Mr. Dan Jeffries generated several unique concepts in the computer simulations for the power budget calculations. Mr. Yugender Reddy helped greatly in the data processing aspects of the program.

The cooperation and work of all these individuals contributed greatly to the value of this report.

Leo Lawaine

SUMMARY

SHUTTLE, STATION AND SATELLITE COMMUNICATIONS PROGRAM

The intent of this program is to develop a parametric approach to analyze and evaluate the performance of any link or links of a satellite relay system. The approach factors into the calculations the constraints of coherent radiofrequency interference (RFI), multipath, and equipment design. To this end the report is divided into three sections dealing with Spread Spectrum (SS) Techniques (Section 1), Power Budget Calculations (Section 2), and Required Capabilities and Design Factors for Tracking and Data Relay Systems TDRS (Section 3).

Section 1 analyzes SS techniques and develops a basic TDRS Communications model incorporating SS techniques. The model consists of flow diagrams and a calculation procedure to determine contrast ratios and performance margins under RFI and multipath conditions.

A PN code that uses hybrid-sum sequences is described and the effect of the code structure on SS system performance is analyzed. To illustrate the capability of the PN spread spectrum system, a typical space PN-transponder design is reviewed.

Section 2 develops detailed models of the TDRS return link (USER→TDRS→GRD) high data rate (HDR) telemetry channel. The physical model shows system parameters and variables, including the associated RFI, multipath, thermal noise sources, and signal factors. This model is basically structured from two submodule links, USER→TDRS and TDRS→GRD. The two sublinks can be used with slight changes to synthesize any TDRS system or other

spaceborne systems links.

The digital computer model is derived from the two submodule links for four selected modes of operation designated as

CASE 1 = NRFI, NSS, NPG*
CASE 2 = NRFI, SS, PG
CASE 3 = RFI, NSS, NPG
CASE 4 = RFI, SS, PG

The computer simulation automatically calculates link power budgets, signal performance margins (energy and power), and feasible data rates for severe operational conditions. Normal power budget calculations are modified (using SS techniques) to take into acccount the effects of RFI, multipath, and coherent jammer interference (intentional or not). Multipath and RFI are not considered potential problems at X and K_u bands; however, one of the primary justifications for the SS system at these bands is the IRAC requirements as to flux density on the earth's surface.

Detailed power budget calculations for the return link (USER→TDRS→GND) are based on the assumption that multipath interference occurs in the USER to TDRS link. This assumption is valid for the following conditions:

- Antenna directivities of USER and TDRS are not sufficient to effectively counter multipath.
- TDRS is in near vertical position with respect to ground station.
- GND antenna directivity is sufficient to counter multipath from TDRS.

The relative advantages and disadvantages for SS techniques are considered. Specific items in the power budget calculations are defined and clarified. The computer model uses a coding technique which permits auto-

*PG stands for processing gain and N means "no" -- e.g., NPG = no PG.

matic processing and calculations for any number of cases. Each case may have any number of sets of data involving any number of input and output parameters and variables.

Section 3 deals with the major required capabilities and design factors of the TDRS relay system. A complete space/ground configuration of all possible links in a system is shown in Figure 2-3 and discussed in the text. Emphasis is on information modes, modulations, transmission frequencies, bit rates, transmitter powers, antenna types, and antenna gains.

The overall TDRS relay operation must be considered as a total systems effort involving complex hardware equipment, software designs, and highly skilled manpower.

This report of the Shuttle, Station, and Satellite Program completes the initial contractual requirements. As a follow-on program the computer model for the parametric design approach could be made more valuable and flexible if additional design features are incorporated in the computer program. These features would include the following additional calculations as part of the link subroutines:

- Transmitting parameters: circuit loss, antenna gain, antenna pointing loss, antenna scan loss.
- RF variable: polarization loss.
- Receiving parameters: circuit loss, antenna gain, antenna pointing loss, antenna scan loss, modulation loss, processing gain, channel bit rate, energy-to-noise spectral density ratio, coherent RFI power.

A TDRS→TDRS link subroutine should also be developed; this will require only a minor modification of the TDRS→GRD subroutine.

With the inclusion of the above additional program elements to the present program, the computer simulation of a complete TDRS relay system could be done very accurately and very quickly. In fact, the computer model with its coding technique, automatic processing of data, and detailed printout format can analyze and evaluate thousands of TDRS relay systems designs in less time than normally required for one manual calculation.

The results of this overall parametric computer approach leads to a performance margin figure of merit. Tradeoffs in cost, complexity, and weight can then be evaluated against the performance margins to determine an optimum satellite relay systems design. This optimization takes into account the effects of a wide range of parameter and variable values for the technical, operational, and environmental systems factors.

APPENDIX D

D.1 DISCUSSION AND SUMMARY OF MAJOR FACTORS FOR WIDE BAND COMMUNICATIONS SYSTEMS

INTRODUCTION

The evaluation is concerned with major factors and conclusions in the design and operation of a complete Space Station/TDRS configuration. This material deals with significant parameters, modulations, selected communications techniques (wideband/spread spectrum, narrowband, multiple access discrete address), RFI interference (special filter design), multipath, pseudo-random codes, propagation effects, multiplexing voice and data, range and range-rate tracking, television.

The principal communications factors and SS techniques are analyzed. This information is used to uncover the best trades among the parameters, and finally develop the most suitable communications models for synthesizing TDRS systems designs. VHF links between the systems components is emphasized in the analyses because of bandwidth and power constraints. Also worst case conditions and adequate systems margins is assumed.

D.2 SUMMARY OF MAJOR FACTORS AND PARAMETERS

1. Required Capabilities of Multipoint Communications Systems.

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   1.1 Multiple access involving random/discrete address (RADA) anywhere. Spread spectrum techniques and the most suitable random dial-up procedures (with minimum time) are required.

   1.2 Rejection of man made interference (RFI).

   1.3 Immunity to multipath.

   1.4 Reliable range and range-rate tracking by the MSFN.

   1.5 Sufficent transmitter power in all system components to provide the required bit error rate (BER) and voice intelligibility. In particular, the power conservation from TDRS is emphasized so that any channel operates at low edge of acceptable S/N ratio.

   1.6 Capability of handling all data rates (low data rate, high data rate and very high data rate) with the most suitable type of modulation.

2. Significant Parameters

   Significant parameters are first described. Values of these parameters and associated variables are used in the communications link configurations and power budget analysis now being performed. This material will also include coherent bandwidths, fading bandwidths, doppler, and antenna anomalies (result of omnidirectional pattern when used with satellite).

3. Anti-Multipath Capabilities

   Spread spectrum and adaptive techniques are investigated to overcome multipath modulation. A convenient means is needed for ground uses to talk to other components of the system with absolute minimum in switching and dialing time.

3. Multipoint Communications

   Wide bandwidth (spread-spectrum) techniques are investigated for their relative advantages over narrow band operation - particularly for time-frequency coding techniques. In general, multiple access and random access discrete address (RADA) are considered jointly.

5. Pseudo-Random Codes (Gold Codes)

Correlation properties of these codes are used for pseudo-noise multiplexing of many simultaneous users through common DRS channel. Each user is assigned a pseudo-noise Gold code for multiple access and positive identification at the ground station.

6. Quantizing Resolution

The desired A/D quantizing resolution is limited by the maximum allowable bit error rate (BER). This required BER is a function of amplitude statistics for analog information. The BER is also a function of the number of bits used in the PCM System. A typical BER is 10^{-5} for a 7-bit PCM System.

7. Forward Error Control

Convolutional encoding at the user and sequential decoding at the ground station enhance over-all system performance. Present circuit technology coupled with forward error control approach makes an attractive way.

8. Range and Range Rate Tracking

Range and range rate tracking is evaluated for user position error in terms of the inaccuracies in tracking the DRS, inaccuracies in the ground station position, and the tracking error of a user of one or more tracking TDRS's.

9. Hardware Factors

The hardware must be reliable, low power, cost effective and high density package. The relative advantages of modulation approaches is considered in terms of reliability, cost, power, size, and weight.